

Purdue University
Purdue e-Pubs

International Compressor Engineering Conference

School of Mechanical Engineering

1998

Compressor Capacity Control: A New Direction

J. Loprete

Bristol Compressors

B. Johnson

Bristol Compressors

Follow this and additional works at: <https://docs.lib.purdue.edu/icec>

Loprete, J. and Johnson, B., "Compressor Capacity Control: A New Direction" (1998). *International Compressor Engineering Conference*. Paper 1322.

<https://docs.lib.purdue.edu/icec/1322>

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact epubs@purdue.edu for additional information.

Complete proceedings may be acquired in print and on CD-ROM directly from the Ray W. Herrick Laboratories at <https://engineering.purdue.edu/Herrick/Events/orderlit.html>

COMPRESSOR CAPACITY CONTROL: A NEW DIRECTION

Joe Loprete
Executive Vice President

Bill Johnson
Engineering Manager

Bristol Compressors
Bristol, Virginia, 24202

ABSTRACT

An ideal capacity control system would make continuous adjustments in capacity to match load, would have full load efficiency that is unaffected by the control mechanism, would have no loss in efficiency at part load, would have reduced starting torque requirements, would have no reduction in compressor reliability, would have no reduction in compressor operating range and would reduce compressor vibration and sound level at part load operation. Previous methods for capacity control (1) have controlled suction pressure by throttling, (2) have controlled discharge pressure, (3) have returned discharge gas to the suction inlet, (4) have opened the cylinder discharge port to suction while closing the port to the discharge manifold, (5) have utilized two speed compressors, (6) have used inverters to vary the compressor speed, (7) have closed off the cylinder inlet, and (8) have utilized multiple compressors. These methods for capacity control have high applied cost and have not been used to any extent in the room air and residential air conditioning markets. Some of these methods have been used in mini-splits and multi-evaporator mini-splits at a significant cost penalty.

INTRODUCTION

A new capacity control concept, for reciprocating compressors, that can reduce capacity by de-activating a piston or pistons when part load capacity is required has been introduced. The compressor utilizes a single or three phase motor that can provide full speed operation in both a clockwise and counter clockwise shaft direction. The compressor provides full load capacity when the shaft is rotated in one direction and part load capacity when it is rotated in the opposite direction. Part load capacity is accomplished by an eccentric rotate-able throw block, which rotates 180 degrees so that its' centerline is in line with that of the crankshaft, thus neutralizing one of the pistons.

The applied cost for this method of capacity control would include the following items: a motor that can provide full speed operation in both directions of shaft rotation, a multiple piece shaft that incorporates an eccentric rotatable throw block, a standard mechanical or electronic two stage thermostat, an additional contactor, a simple control board and fan speed controls for the indoor/outdoor fans if optimum results are desired. The compressor will require one hermetic terminal where as a two speed compressor requires the use of two hermetic terminals. This method of capacity control provides substantial pay back during the first few years of operation that will more than offset the additional cost of the air conditioning system that utilizes it. Figure 1 shows component position for two cylinder operation and Figure 2 shows component position for one cylinder operation.

When properly designed, this method can be used to increase efficiency on residential air conditioning systems from 10 to 12 or from 12 to 14 Seasonal Energy Efficiency Ratio (SEER) when a simple retrofit is implemented. The simple retrofit for capacity control would include piston de-activation and a tapped indoor blower motor change to maximize the system efficiency. The use of a variable speed indoor blower or a 60/30 hertz inverter, when included with the above features, will increase the system's efficiency from 10 to 14 SEER.

This capacity control concept is also a natural for heat pump applications. The heat pump would utilize one cylinder for operation during the cooling season, the same one cylinder for the mild weather heating season and two cylinders for the cold weather heating season. This postpones the use of supplemental electric strip heating for another 15 degrees of lower ambient temperature. The Heating Seasonal Performance Factor (HSPF) in the heat pump mode can exceed 9 when this method is utilized.

PERFORMANCE ANALYSIS

The R and R Supply Company's "Computer Programs for Air Conditioning System Balancing" were utilized to substantiate the efficiency improvement with piston de-activation, a reduction of indoor air flow and a reduction of outdoor air flow at the part load operating conditions. These programs are utilized throughout the air conditioning and refrigeration industry and have provided excellent correlation between computer simulations and actual performance tests that are performed in controlled environment rooms.

ARI Standard 210/240 for "Unitary Air Conditioning and Air-Source Heat Pump Equipment" was utilized to substantiate the energy savings with this method of capacity control. This standard requires steady state performance tests at both full and part load capacity prior to determining the Seasonal Energy Efficiency Ratio with capacity control. Steady state performance tests must be done at the "A" and "B" standard rating conditions per the above mentioned standard. Test conditions for the "A" point are with 80°F DB / 67°F WB indoor air entering and with 95°F DB / 75°F WB outdoor air entering. Test conditions for the "B" point are with 80°F DB / 67°F WB indoor air entering and with 82°F DB / 65°F WB outdoor air entering.

Computer simulations were performed at the above test conditions and a method for calculating a SEER for units with cylinder unloading was used. This method is detailed in paragraph A5.1.3 of ARI Standard 210/240 (Appendix A). A distribution of fractional hours in temperature (outdoor °F) bins was used for calculation of the SEER for a compressor with cylinder unloading. A computer data set for a 5 ton air conditioning system with a 10 SEER rating was used as a starting point for the performance analysis.

It was determined that the efficiency of a 5 ton air conditioning system could be increased from 10 to 12 SEER if piston de-activation was implemented. This was accomplished by tapping the indoor blower motor to get 90% of the full load air flow (1,800 CFM) and by utilizing full outdoor (3,400 CFM) air flow. The sensible heat ratio (SHR) of the indoor supplied air increased from 0.72 at full load capacity to 0.90 at part load capacity. The sensible heat ratio is equal to the sensible capacity divided by the total capacity. Latent capacity (the ability to remove moisture from the indoor air) decreased from 28 percent of total capacity at full load to 10% when part load capacity was utilized. This may cause some discomfort when the indoor air is saturated with moisture.

The above work was done with a two cylinder compressor with 50/50 split capacity. The 50/50 split capacity compressor is one with the same bore and stroke applied to each cylinder. It was thought that there may be an advantage to using a different split on the compressor. Therefore, simulations were done with 90% evaporator and 100% condenser air flow to determine performance with a 40/60, 50/50 and 60/40 split in compressor capacity. The 40/60 split provided good SEER (11.9) but had a high SHR (1.00) that may affect indoor comfort. The 60/40 split provided good SEER (11.9) but had the lowest SHR (0.83) which helps maintain indoor comfort. The 50/50 split was more ideal for air conditioning systems: best SEER (12.1) and good SHR (0.90). Figure 3 shows the simulated performance of an air conditioner with 40%, 50% and 60% part load capacity.

CONCLUSIONS

In the past, compressor capacity control has not been successfully applied to room air and residential air conditioning equipment because the efficiency was not increased sufficiently enough to offset the applied cost of adding the capacity control mechanisms and controls. These new concept compressors that can de-activate a cylinder or cylinders when the shaft is rotated in the opposite direction can reverse this trend. Advantages for this type of compressor design are as follows:

1. Compressors that can de-activate piston(s) have fewer start/stop cycles than those that operate with full load capacity at all times. This will improve the reliability of the compressor.
2. The compressor efficiency at the ARI test condition drops off slightly when the compressor is operated in the reverse direction with part load capacity.
3. The majority of the run time will be with part load compressor operation and reduced air flows which will provide lower sound levels for habitation both inside and outside the dwelling.
4. Air conditioners with an 11 SEER (Seasonal Energy Efficiency Ratio) ratings and above have the lowest cost when this capacity control method is utilized. Higher SEER levels are more readily attainable.
5. Compressors that can de-activate a piston(s) are more capable of matching the indoor load.
6. Part load operation can provide 100% of the indoor cooling up to an outdoor ambient temperature of 95°F.
7. Improvements can be made to existing air conditioning systems without redesigning heat exchangers, sheet metal and air flow systems. Condensing units for the 10, 12 and 14 SEER product lines can be standardized.
8. Air conditioning operation is more continual which will provide a more constant indoor temperature along with better humidity control.
9. Postpones the use of supplemental electric strip heating, in heat pumps, for another 15 degrees of lower ambient temperature.
10. Consumers will benefit from the lower energy costs.

REFERENCES

1. The R & R Supply Company, Inc., "Computer Programs for Air Conditioning System Balancing"
2. Air Conditioning & Refrigeration Institute, ARI Standard 210/240 "Unitary Air Conditioning and Air-Source Heat Pump Equipment"

TWO CYLINDER OPERATION

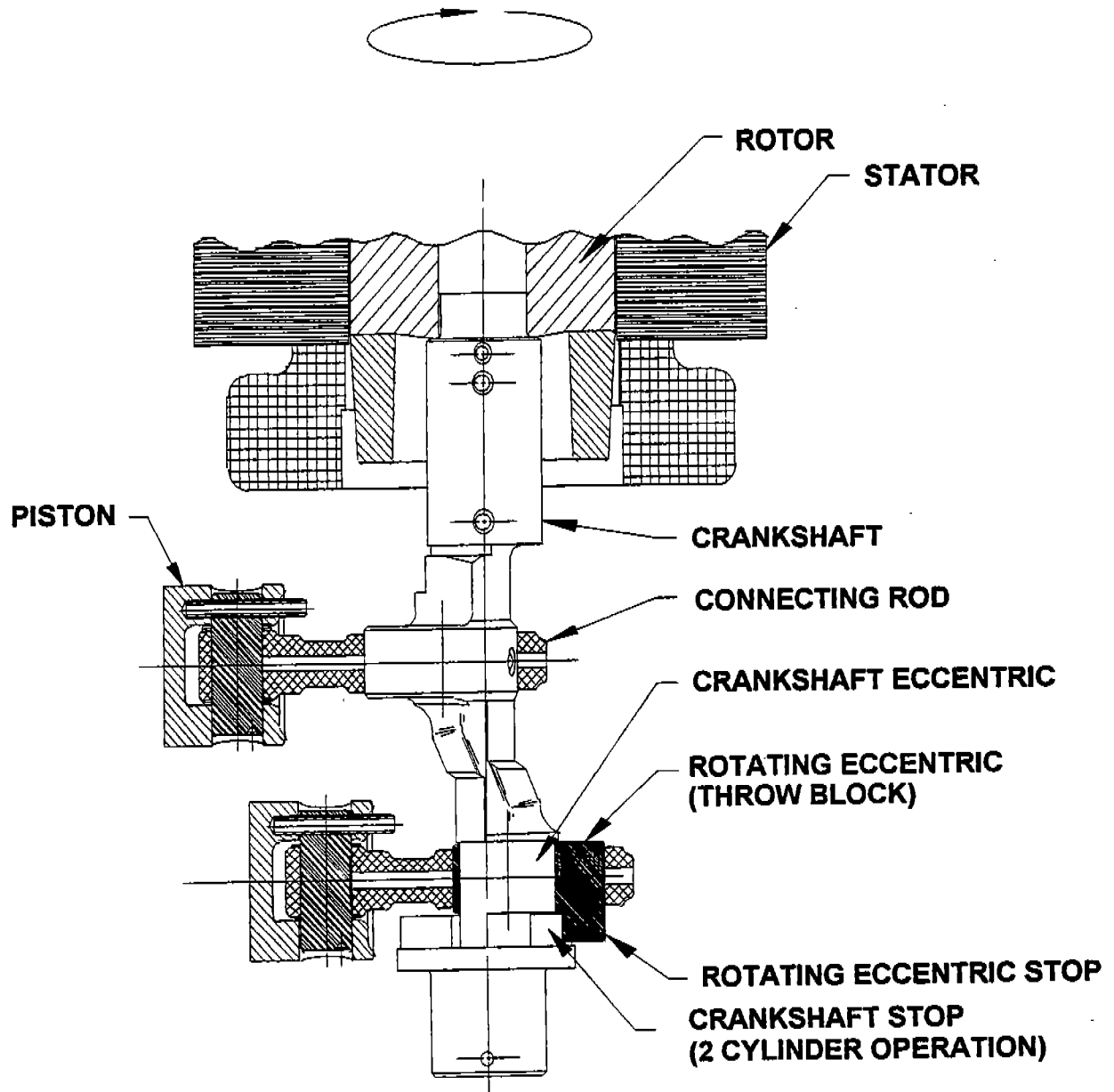


Figure 1

ONE CYLINDER OPERATION

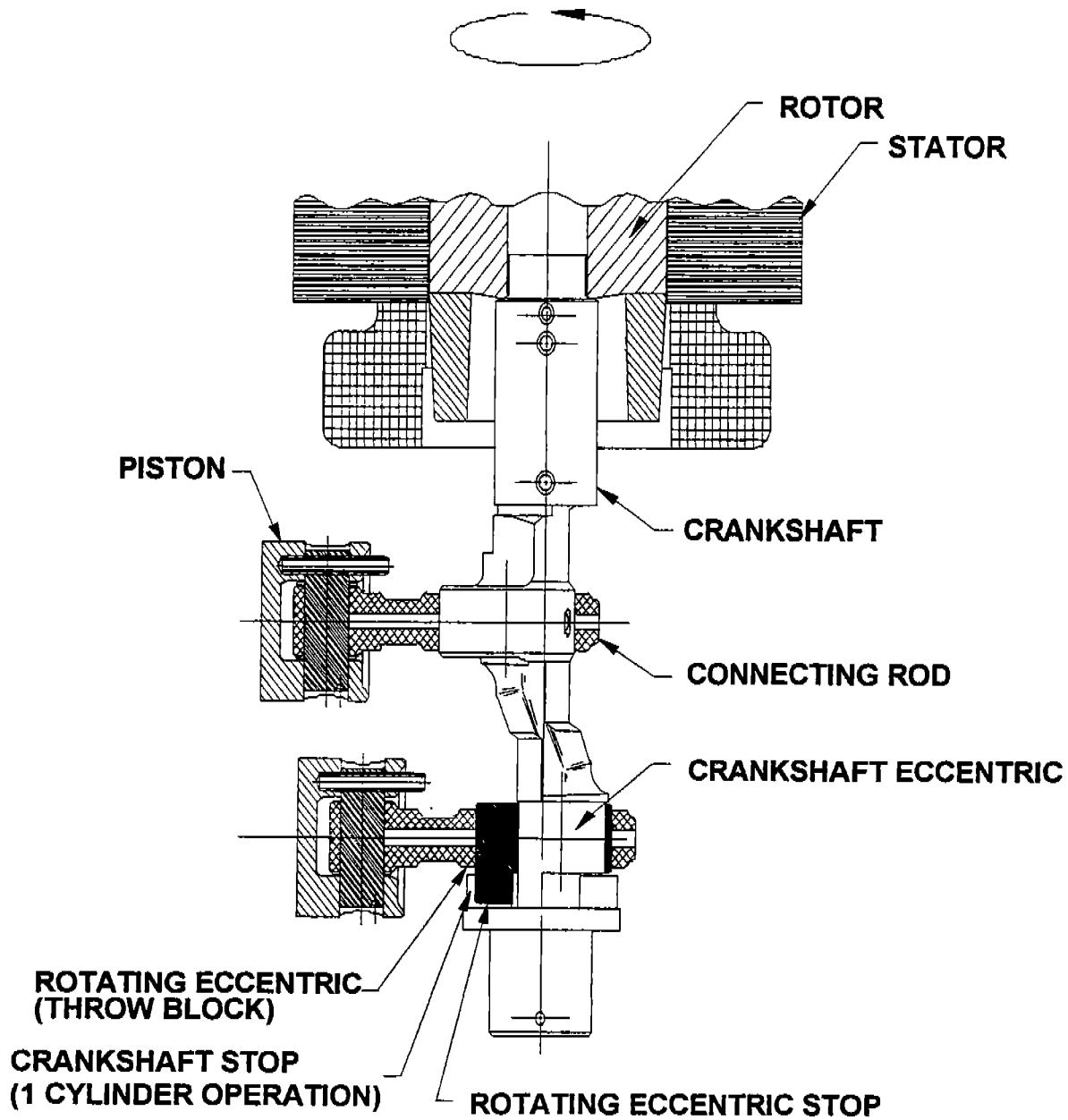


Figure 2

**5 Ton Air Conditioning System with 40%, 50% and 60% Part Load
Simulated Performance with Farr Program
(with 80/67 °F Indoor Entering Air Temperature)**

